The efficacy of silicaceous dust alternatives to organophosphorus compounds for the control of storage mites

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Abstract
Mites are important and destructive pests of stored products. They cause direct damage by destruction of the germ, cause taints and allergies and transmit fungi and bacteria and have been implicated in the transmission of prions. Conventional organophosphorus pesticides are the only chemicals approved for use on stored grain and oilseeds in the UK but are not very effective against mites.

Silicaceous dusts are one alternative to organophosphorus pesticides which have proved effective against storage insects as structural treatments and as surface treatments and have been registered for use in countries including the USA, Canada, Australia. The experiments reported here investigated the effect on developing mite populations of dusts based on freshwater and saltwater diatoms as well as amorphous silica.

At 15°C, 75% r. h., doses of 1 – 5 g/kg for all four silicaceous dusts generally gave > 99% control of Acarus siro, with 3 – 5 g/kg required against Tyrophagus putrescentiae and Glycyphagus destructor, the latter species being the least susceptible. This high dose precludes use as an admixture treatment due to cost and effect on grain flow but is acceptable as a top-dressing as part of an integrated storage strategy or as a fabric treatment.

Introduction
Mites are very common pests of stored cereals and oilseed in the U. K. As well as the damage they cause to stored commodities, there are potential health risks to workers by the development of serious allergies following exposure to the pests. Mites have also been implicated in the transmission of fungi, bacteria and prions. In the U. K., stored grain protection has relied heavily on bulk admixture with pesticides. The only contact pesticides approved for use on stored grain and oilseeds are the organophosphorus (OP) compounds pirimiphos-methyl, etrafos and chlorpyrifos-methyl. However, none of these pesticides are now particularly effective against field strains of mites and resistant populations have been detected. As well as concerns regarding the development of resistant pests, the costs and consumer resistance to toxic chemicals in food, have led to increasing pressures for a reduction in pesticide use, and the need to find alternative compounds.

Inert dusts have been used traditionally as a stored grain protectants, and there is increasing interest in their use as alternatives to chemical control measures. A number of studies on the efficacy of inert dusts against stored product insects have been reported and they have proved effective as grain protectants (Desmarchelier and Dines, 1987), as structural treatments in empty stores (Bridgeman, 1994) and as surface treatments in conjunction with aeration (Nickson et al, 1994). Diatomaceous earths (DEs) have been registered for storage use in USA, Canada, Australia, Japan, Indonesia and Saudi Arabia.

The products are based on inert materials such as silica gel or diatomaceous earth and contain no insecticide or knock-down agents. They are pesticide-free, effective against chemically resistant species, and are stable at high and low temperatures (McLaughlin, 1994). In contrast to chemical insecticides which induce rapid immobilisation and kill, the action of inert dusts is slower so extended exposure periods of 20 days or more, may be required to eliminate an insect population (McLaughlin, 1994). Most products, at the appropriate concentration, provide protection for at least 12 months (McLaughlin, 1994).

Inert dusts act by physical means, with insect mortality thought to occur by desiccation as a result of the dust adsorbing lipids from the cuticle (Ebeling, 1971).

Several studies have investigated the efficacy of inert dusts against parasitic mites but knowledge of the effects of inert dusts against stored product mites is very limited. Cook and Armitage (1996) investigated the efficacy of 'Dryacide', applied to wheat at 1g/kg and 3 g/kg, against Acarus siro L. and Glycyphagus destructor Schrank. At 14% moisture content (mc) and 17.5°C, both doses were completely effective at controlling both species. At 16% mc and 17.5°C, 3g/kg was fully effective against A. siro but not against G. destructor. Fields and Timlick (1995) found that the product 'Super Insecolo' reduced predaceous and grain feeding mite species by over 98% when applied to wheat at 50 ppm.
The use of inert dusts as grain protectants may become increasingly more significant as alternatives to conventional chemicals are sought. Their advantages include low mammalian toxicity, cost effectiveness, persistence and lack of toxic residues on grain. Disadvantages have included the very high treatment rates required, which affect the physical properties of the grain, particularly bulk density, angle of repose and flow rate (Jackson and Webley, 1994).

Inert dusts are also less effective at high relative humidities and moisture contents, which is a major consideration for their use as grain protectants in the UK. The higher doses that may be required for control may have an adverse effect on the physical properties of the grain. However, these disadvantages would be minimised if dusts were used as a surface treatment, in conjunction with cooling as part of an integrated storage strategy.

Due to the particle size of some dusts they are considered to be respirable and therefore represent a potential hazard to users (Golob, 1997). However, dusts of larger particle sizes are relatively safe to use with minimum protective equipment (dust mask). Diatomaceous earths may be of marine or freshwater origin and usually contain about 90% SiO₂ (Golob, 1997).

Marine diatoms contain high quantities of crystalline silica, which can result in silicosis and other respiratory diseases. The formulations of the inert dusts ‘Protect-it’ (Super Insecto), from Canada and Insecto, from the USA, were of marine origin (Subramanyan, in press). Crystalline silica shows limited carcinogenic effect (Anon, IPDA cited in Quarles, 1992).

Dryacide is based on freshwater diatoms but coated with a silica aerogel (Subramanyan, in press). silica aerogels are efficacious at lower rates than diatom-based products. They are produced by drying aqueous solutions of sodium silicate but their low dust density has prevented their use alone because of potential inhalation hazards (Golob, 1997).

‘RID IP’, the UK product, is amorphous precipitated silica. Compounds of this description usually have a SiO₂ content of 98% or more (Golob, 1997). According to IARC amorphous silica is not carcinogenic.

The aim of these initial experiments was to evaluate four siliceous dusts for the protection of stored grain against mite infestation. Because the aim was to identify possible replacements for OPs as adjuvance treatments, the most appropriate method of evaluation would be to assess the compounds when applied directly to grain. Efficacy needed to be evaluated against the most common mite pests found in stored grain under typical U.K. storage conditions. Also, because different mite stages may have different tolerances, the compounds were evaluated against mixed stages and assessed for periods long enough to include the passing of at least 2 generations.

**Materials**

**Wheat**: The grain used was pesticide-free, English milling wheat with a moisture content of about 15%, as determined using the oven method (BS4317), by drying in a ventilated oven at 130°C for 2 hours. The wheat was stored in plastic bags in a freezer for at least 21 days prior to use to ensure any mites coming in on the grain were killed.

**Mites**: The mites used were laboratory susceptible strains of *A. sivo*, *Tyrophagus putrescentiae* Schrank and *G. destructor*. All had been reared at the Central Science Laboratory (CSL) in constant conditions of 15°C and 75% rh without exposure to pesticides. Mixed stages of unknown age were used.

**Methods**

**Preparation and treatment of grain**. Batches of 493 g of whole wheat and 7 g of kibbled wheat were weighed out and mixed together into 1.5 l ‘Kilner’ jars, prior to application of the dusts. The kibbled wheat served as an initial food supply for the mites to aid establishment on the whole grains and prevent population crashes.

The siliceous dusts were applied at 5, 3, 1 and 0.5 g kg⁻¹ by weighing out the appropriate amount and adding directly to the grain in jars. One batch remained untreated to act as a control. After treatment the batches of treated and control grain were mixed on a tumbler for 15 minutes to ensure an even distribution and stored at room temperature overnight. The jars were then tumbled for a further 10 minutes. Each batch of treated and control grain was divided into approximately 50 g lots, put into 120 ml wide-necked baosass jars and closed with filter paper lids. Six replicate jars were prepared for each treatment and each mite species. The jars were left to equilibrate in the test conditions of 15°C and 75% rh for 24 hours.

**Bioassay**: A heaped spatula containing approximately 0.01 g of mixed stage mites was placed into each jar and the jars were re-closed with a filter paper lid. The jars were incubated in the test conditions for periods long enough to be included the passing of at least two generations. Since the different mite species have different developmental rates from egg to adult, exposure periods varied for each species. Therefore, assessments of the *F₁* and *F₂* generations took place at approximately the following number of days after treatment:

<table>
<thead>
<tr>
<th>Mite species</th>
<th><em>F₁</em> assessment</th>
<th><em>F₂</em> assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acarus sivo</em></td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td><em>Tyrophagus putrescentiae</em></td>
<td>50</td>
<td>110</td>
</tr>
<tr>
<td><em>Glycyphagus destructor</em></td>
<td>45</td>
<td>100</td>
</tr>
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</table>
Three replicate jars were assessed at each assessment period. The contents of each jar were sieved over a 710 μm mesh and the sievings examined under a low power binocular microscope. The numbers of live mites were counted using the technique of Solomon (1962) using a disc divided into areas. After the assessments the moisture content of the grain was re-checked using an oven method (BS 4317).

The mean percentages of inhibition were calculated by comparing numbers of mites in the treatments with numbers in the untreated controls.

Results and Discussion

All the dusts inhibited the F₁ generation of the flour mite, *Acarus siro* and the mould mite, *Tyrophagus putrescentiae*, by more than 95% at all doses between 1 and 5 g kg⁻¹. However the cosmopolitan food mite, *Glycyphagus destructor* proved less susceptible and a dose of 3 g/kg was required to inhibit the population by between 88% and 100% after one generation (Figs. 1–4). Of the four products tested, the amorphous silica, 'RID IP' performed consistently best at the F₁ assessment. For instance, at 0.5 g/kg, against *G. destructor*, the F₁ populations were 1027 (592–1360), 1536 (1512–1872), 3445 (2024–4384), 4048 (2464–5088) and 4875 (4088–5752) for 'RID IP', Protect-it, Insecto, Dryacide and the control respectively.

The populations of all three species of mites in the controls declined between the F₁ and F₂ assessments. This is because the high populations of mites would have exhausted their limited food supply (Solomon, 1969). In these conditions it is likely that the mites hollow out the cereal germ and cannot access the endosperm through the dividing cellular layer (Parkinson, 1990). In addition, there was considerable variation between replicates, especially at the F₂ assessments. Both these factors mean that the estimates of control were unduly pessimistic.

**Acknowledgements**

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![Fig. 1. Percent inhibition by four doses of 'RID IP' of populations of three mite species (expressed as a proportion of populations on untreated grain) at 75% r.h., 15°C. F₁ assessment.](image-url)
Fig. 2. Percent inhibition by four doses of 'Protect-it' of populations of three mite species (expressed as a proportion of populations on untreated grain) at 75% r. h., 15°C. F₁ assessment.

Fig. 3. Percent inhibition by four doses of 'Dryacide' of populations of three mite species (expressed as a proportion of populations on untreated grain) at 75% r. h., 15°C. F₁ assessment.
Fig. 4. Percent inhibition by four doses of 'Insecta' of populations of three mite species (expressed as a proportion of populations on untreated grain) at 75% r. h., 15°C F1 assessment.

References


